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Shoreline and Dock Modifications in Lake Washington

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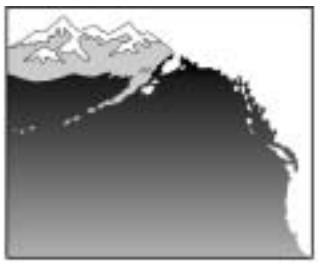

University of Washington
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Key Words

aerial photographs, City of Seattle, chinook salmon, dock modification, GIS, Lake Washington, littoral zone, Oncorhynchus tshanytscha, shallow-water habitat, shoreline habitat

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Executive Summary

The goal of this study was to estimate to what extent the historical shoreline of Lake Washington has been modified by docks and retaining structures. Such information is a vital step in determining to what degree shoreline modifications affect endangered populations of chinook salmon (*Oncorhynchus tshawytsha*), as juvenile chinook use the littoral zone in Lake Washington for rearing and migration to the ocean. We used aerial photographs from the years 1962, 1974, 1990, and 1999, and conducted field surveys to quantify the historical rate of dock increase, as well as classify current shoreline structures and habitat types.

As of the year 2000, there are 2,737 docks along the shoreline of Lake Washington, the majority of which are recreational docks that are low (<2 m) above the water. The annual percent increase has been steadily declining in recent years, suggesting that the shoreline is approaching saturation. Retained shoreline, which represents 70.65% of the total shoreline, comprises riprap or bulkhead. Unretained shoreline, which represents 29.35% of the total shoreline, is either beach, naturally vegetated, or landscaped waterfront. Results from our habitat surveys show that the typical shoreline is partially exposed to wave energy, has a terrestrial shoreline with a moderately inclined slope, is characterized by garden/lawn in the upland cover, and has a mixed coarse shoreline substrate.

How juvenile chinook salmon react to shoreline modifications is still somewhat unclear, and future research should specifically address such issues. Knowledge is distinctly lacking concerning the possible effects of shoreline modifications on beach structure and function. Managing such aspects of shoreline development may be important in ensuring that vital habitat is available to enhance the recovery of endangered salmonid populations.

Introduction

The shoreline of Lake Washington has been increasingly developed in the last century due to urban sprawl from the Seattle metropolitan area (Fig. 1). Maintaining a balance between encroaching development and the natural environment has recently escalated with listing by the National Marine Fisheries Service of Puget Sound chinook salmon (*Oncorhynchus tshawytsha*) as a threatened species in March 1999. Juvenile chinook use the littoral zone in Lake Washington for rearing and migration to the ocean (Piaskowski and Tabor 2001). These same shallow-water areas are modified by docks and retaining shoreline structures. Managing shoreline development may be important in ensuring that vital habitat is available to enhance the recovery of endangered salmonid populations.

Lake Washington has a history of anthropogenic alterations to its hydrology, including construction of the Lake Washington Ship Canal and diversion of several river systems (Chrzastowski 1983). With the completion of linking Lake Washington to Puget Sound in 1916, the water level of Lake Washington was lowered 8.8 feet, and the flushing of Lake Washington was modified by having the Cedar River flow into the lake (Chrzastowski 1983). With this restructuring, salmonid populations now had a freshwater–saltwater rearing and migration corridor through Lake Washington.

The main goal of this report is to examine to what extent the historical shoreline of Lake Washington has been modified by docks and retaining structures. We seek to build on the efforts of other recent local initiatives by adding quantitative data to the historical rates and current amount of shoreline development. Hockett (1976) examined rates of dock increase from the 1940s to the 1970s, and we will incorporate his data with our own to expand our view of shoreline development. The City of Seattle has recently completed shoreline surveys of their boundaries (Parametrix and NRC 1999), as well as identified factors affecting chinook populations (Parametrix et al. 2000). The City of Bellevue has also summarized the potential impacts of shoreline development on salmonids (Kahler et al. 2000).

Objectives

Our objective was to classify dock and shoreline modifications as follows:

Inventory of Dock Modifications

- Characterize the historical rate of dock increase on the Lake Washington shoreline.
- Classify docks into categories of small recreational docks and large marina docks.
- Classify the current number of docks that are high above water (>2 m) and low above water (<2 m).
- Classify the current number of docks that have attached buildings or floating docks or both.

Classify Shorelines and Shoreline Modifications

- Classify the current shoreline into categories of retained structures (riprap, vertical bulkhead, sloping bulkhead) and unretained (beach, natural vegetated, landscaped).
- Classify large segments of the shoreline into general categories of substrata type, shoreline energy exposure, shoreline geomorphology, and upland cover.

Materials and Methods

Dock Counts

Historical Lake Washington development was measured by counting the number of docks. Hockett (1976) counted docks from aerial photographs for the years 1942, 1952, 1970, 1971, 1972, 1973, and 1974. To add to this, we counted docks from aerial photographs for the years 1962, 1974, 1990, and 1999 (Table 1*).

We collected additional data in 1962, 1990, and 1999 on the rate of increase, while we used 1974 to check against the measurements of Hockett. In the 1974 measurements of Hockett, he distinguished between recreational docks and large marina docks. This has also been done for all of our measurements. We used Hockett's criteria for this procedure, defined by him as:

> *Recreational docks*: "…associated with a single-family residence, a single-family residence projecting over the water, small marinas which accommodated a few boats and readily identifiable single piers projecting from public or neighborhood parks."
> *Large marina docks*: "…large multifamily or commercial structures which projected over the water, the large pier networks, the large marinas, the large filled areas supporting structures or combinations of the foregoing which formed complexes."

Shoreline Mapping

Mapping of the Lake Washington shoreline, including Mercer Island, was conducted over 4 days of fieldwork in 2000 (8/29, 9/6, 9/15, 9/20). We printed 266 detailed sections of Lake Washington from aerial photographs. The shoreline structures were delineated by marking these maps with color-coded lines while boating slowly along the shoreline at the end of the docks. Shorelines were placed into categories of retained structures (riprap, vertical bulkhead, sloping bulkhead) and unretained shoreline (beach, naturally vegetated, landscaped). For example, a segment that consisted of riprap was designated on the map with a brown marker. Docks were also categorized into classifications of high above water (>2 m) and low above water (<2 m), with/without attached building, and presence of floating docks.

Larger segments of the shoreline were classified in regard to general categories of substrata type, shoreline energy exposure, shoreline geomorphology, and upland cover, based on the National Wetlands Inventory (Cowardin et al. 1979) and Washington Department of Natural Resources (Dethier 1990) classification schemes (Table 2). These large segments were classified whenever our three-person field crew determined a change in the categories; scientific measurements were not utilized. A total of 134 segments were classified in this way for the entire lake. Most categories were easily determined, substrata being the most difficult as it involved observing the underwater substrate from the boat. Substrata pertained to the major substrate type at the shoreline where it could be visualized from the boat; specific checks were made at least once per segment.

Geographic Information System (GIS) Analysis

All dock counts and shoreline mapping measurements were incorporated into GIS format using ArcView 3.2. The docks were counted from each aerial photograph, and a separate point file was created for each year. The shoreline measurements were incorporated by digitizing the shoreline and coding segments to their specific classifications. From this, total linear length of the various categories was determined.

Results

Dock Characteristics

There are currently 2,737 docks in Lake Washington, resulting in an overall frequency of 36 docks per mile (Fig. 2). By 1942, there were already 1,122 docks (Hockett 1976), so in the last 57 years, 1,615 docks were added. The annual percent increase has been steadily declining from 5.7% in the 1940s to 1.8% in the 1960s, and 0.5% in the 1990s (Fig. 2). The majority are recreational docks (96%), which have been increasing at about the same rate

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as the total dock count (Fig. 3). The annual percent increase of large marina dock complexes increased during the late 1970s and 1980s, leading to a doubling in number since 1960 to an overall count of 111 (Fig. 4). Less than 1% of all docks are high above the water (>2 m), and almost all of these high docks have an attached building (Fig. 5). Low docks (<2 m) account for the vast majority of docks (99%), but only 7% of these have an attached building (Fig. 5). Less than 1% of all docks have attached floating docks (Fig. 5).

Shoreline Structures

Retained shoreline, which represents 70.65% of the total shoreline, comprises riprap or bulkhead, while unretained shoreline (29.35% of total shoreline) is either beach, naturally vegetated, or landscaped. (Fig. 6). The linear length of the entire Lake Washington shoreline is 75.98 miles, including Mercer Island but not water gaps such as Montlake Cut. Of this shoreline, 53.68 miles are retained, while 22.3 miles are unretained. Lake level measurements were retrieved from the U.S. Army Corps of Engineers (USACE) Hydraulics and Hydrology Section (range 21.20–21.29 ft) at the Kenmore gage during our fieldwork.

Sectional and City Jurisdiction Analysis

The north section of Lake Washington has the highest dock frequency (43/mile), while the south section has the lowest dock frequency (31/mile), with the middle section being average between the two (36/mile; Fig. 7). However, the percent of retained shoreline structure is less in the north section, having more beach and less riprap and unretained landscaped shoreline than the middle and south sections (Fig. 7).

Shoreline within the city limits of Tukwila has the highest dock frequency (75.7/mile) while Renton has the lowest (16.47/mile; Fig. 8). The cities with the longest amount of shoreline are Seattle (26.24 miles) and Mercer Island (13.9 miles); of these Seattle has a below-average dock frequency (28.7/mile) while Mercer Island has an above-average frequency (44.67/mile). Tukwila also has the highest percent of retained shoreline (91.5%) while Kenmore has the least, owing to the large amount of natural vegetated habitat provided by St. Edwards Park and the mouth of the Sammamish River (Fig. 8). Of the two cities with the greatest length of shoreline, Seattle has a below-average percent of retained shoreline (62.3%) while Mercer Island is above-average (79.3%), owing to the higher percent of riprap than any other city (Fig. 8). The north end of the lake has the most beach habitat, as Kingsgate and Lake Forest Park have the highest percents of beach shoreline (Fig. 8).

General Shoreline Classifications

The typical Lake Washington shoreline is partially exposed to wave energy (Fig. 9), has a terrestrial shoreline with a moderately inclined slope (Fig. 10), is characterized by garden/lawn in the upland cover (Fig. 11), and has a mixed coarse shoreline substrate (Fig. 12).The majority of the shoreline is partially exposed to wave energy, with the least amount of protected areas (Fig. 9). The shoreline geomorphology is almost all moderate or low gradient terrestrial slope with few areas of emergent marsh and stream delta habitat (Fig. 10). The upland cover directly above the shoreline is mostly garden/lawn with less than 20% natural shrub-scrub, forested, or herbaceous habitat, but also without much impervious area (Fig. 11). Mixed coarse substrate and sand have the highest percentages of general shoreline substrate types, followed closely by gravel and beds of submerged aquatic vegetation (SAV), with low values of the finer organics, muds, and mixed-fines (Fig. 12).

Discussion

Human development of natural shorelines in Lake Washington has altered vital salmonid rearing and migration habitat. The shallow-water zone in Lake Washington that juvenile salmon depend on has already been largely modified. Except for “green” areas such as parks, marshes, and river mouths, the majority of the shoreline appears to be approaching maximum capacity for dock construction, as illustrated by the declining increase in recent years (Fig. 2). Perhaps in response to this, large marina docks showed an increase in development in the late 1970s and 1980s, but this too has stabilized recently. With 70% of the total shoreline retained by either riprap or bulkhead, this in essence truncates the shallow-water zone, removing the gradual natural slope. Certain areas of the lake clearly are more modified than others as illustrated by the span of development in different city jurisdictions and geographic sections of the Lake.

It is important to compare our study with other similar ones in the area. There is a 5.3% margin of error between the 1974 dock counts of our data and Hockett’s (1976) data (Table 3). Possible reasons for the higher total count in Hockett’s data include the following: (1) our data have a higher count for large marina docks, which usually consist of a few interlinked docks, potentially adding a higher total number to Hockett’s value if he counted some of these individually as recreational docks; (2) our 1974 aerial photograph is from March and the exact date of Hockett’s 1974 aerial photograph is not known, but other photos from the same series are from later in the summer in July and Au-

gust (Hockett 1976). This could cause differences in the image data based on time of year as dock construction progressed throughout the summer, as well as light reflectance/angles when the photo was taken; and (3) various errors, to quote Hockett (1976; p. 138): "In some cases the photography, especially the mosaic photomaps for 1942, was difficult to interpret. Therefore, the pier counts are considered to be approximations. The difficulties resulted from indistinct images, the complex forms of many large pier and structure inter-relationships, large trees which overhung piers, forested shoreline shadows which masked piers, and light reflections from the lake surface. Attempts were made to clarify the difficulties by study and comparison of photography or imagery of earlier or later time periods. In most cases this technique provided clarification. However, the removal or installation of piers along a specific segment of lakeshore was found to be very difficult to ascertain."

The City of Seattle recently completed a study on shoreline structures (Parametrix and Natural Resources Consultants 1999) producing values similar to ours for North Seattle but markedly different for South Seattle (Table 4). Possible reasons for the differences include the following: (1) the City of Seattle estimated percentages of shoreline structures in increments of 5%, while we measured exact lengths of each shoreline type; (2) lake level could affect the observed shoreline structures at the water edge, and can vary as much as 2 feet throughout the year due to adjustment at the Chittenden Locks (Chrzastowski 1983). For example, sometimes sections of shoreline that we classified as "beach" would have a bulkhead setback from the water edge, and therefore at a higher water level could be classified as "bulkhead." The lake level was not included in the City of Seattle report. However, we retrieved lake level measurements from the USACE Hydraulics and Hydrology Section. Lake levels ranged from 21.20 to 21.29 ft at the Kenmore gage during our fieldwork (8/29, 9/6, 9/15, and 9/20/00), and from 21.98 to 22.22 ft during the City of Seattle's survey (7/8 to 7/16/99). On average, the lake level was 0.89 ft higher during the City of Seattle's survey, which could cause differences in what shoreline exists at the water edge.

Quantifying the historical and current rates of shoreline development along Lake Washington is an important first step in assessing the interactions between such modifications and endangered chinook salmon. Many gaps still exist in our scientific knowledge, most importantly in how juvenile salmon react to shoreline developments as they are rearing in or migrating through shallow-water habitat. Piaskowski and Tabor (2001) have found that retained shorelines and over-water structures create habitat that are avoided by juvenile chinook salmon at night; further, juvenile chinook salmon prefer shallow water with a gradual slope and small to fine substrate. We must also incorporate information on other fish species in the lake, as evidence suggests that piscivores such as non-indigenous smallmouth bass (*Micropterus dolomieui*) prefer habitat surrounding dock piers (Pflug 1981). Future research should seek to examine such interactions with shoreline developments, perhaps assessing many of the potential impacts summarized in the literature review by Kahler et al. (2000).

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FIGURE 1. Historical (left) and current (right) view of the Lake Washington shoreline.

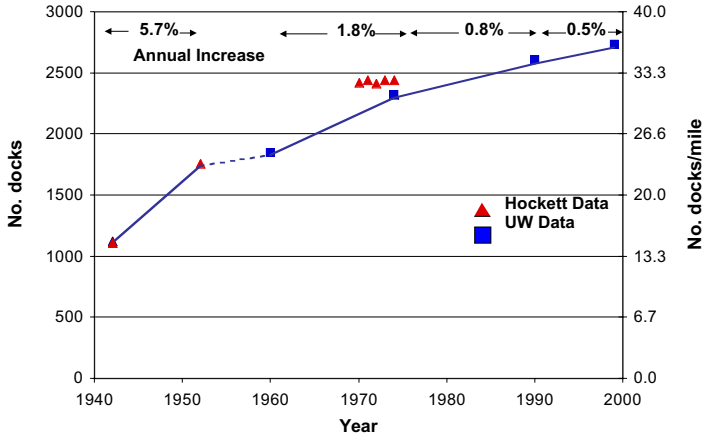

FIGURE 2. Historical change in the number of docks in Lake Washington.

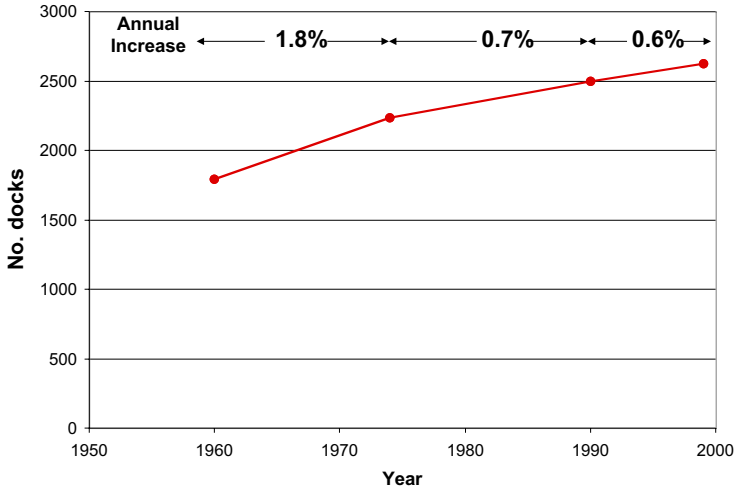

FIGURE 3. Historical change in the number of recreational docks in Lake Washington.

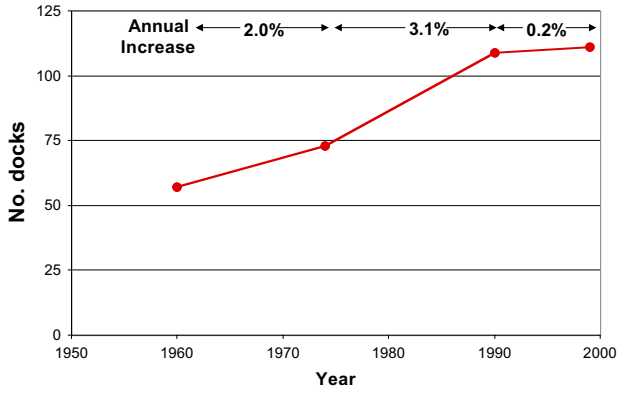

FIGURE 4. Historical change in the number of large marina docks in Lake Washington.

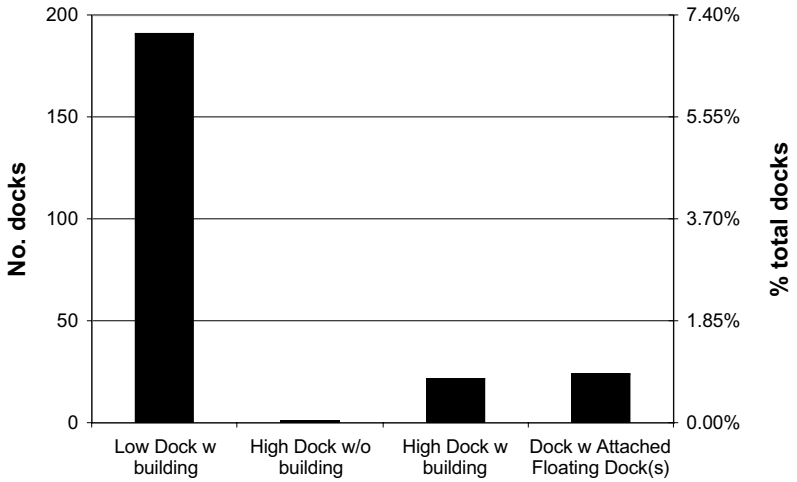

FIGURE 5. Number of high docks (> 2 m above water) and low/high docks with attached buildings or attached floating docks.

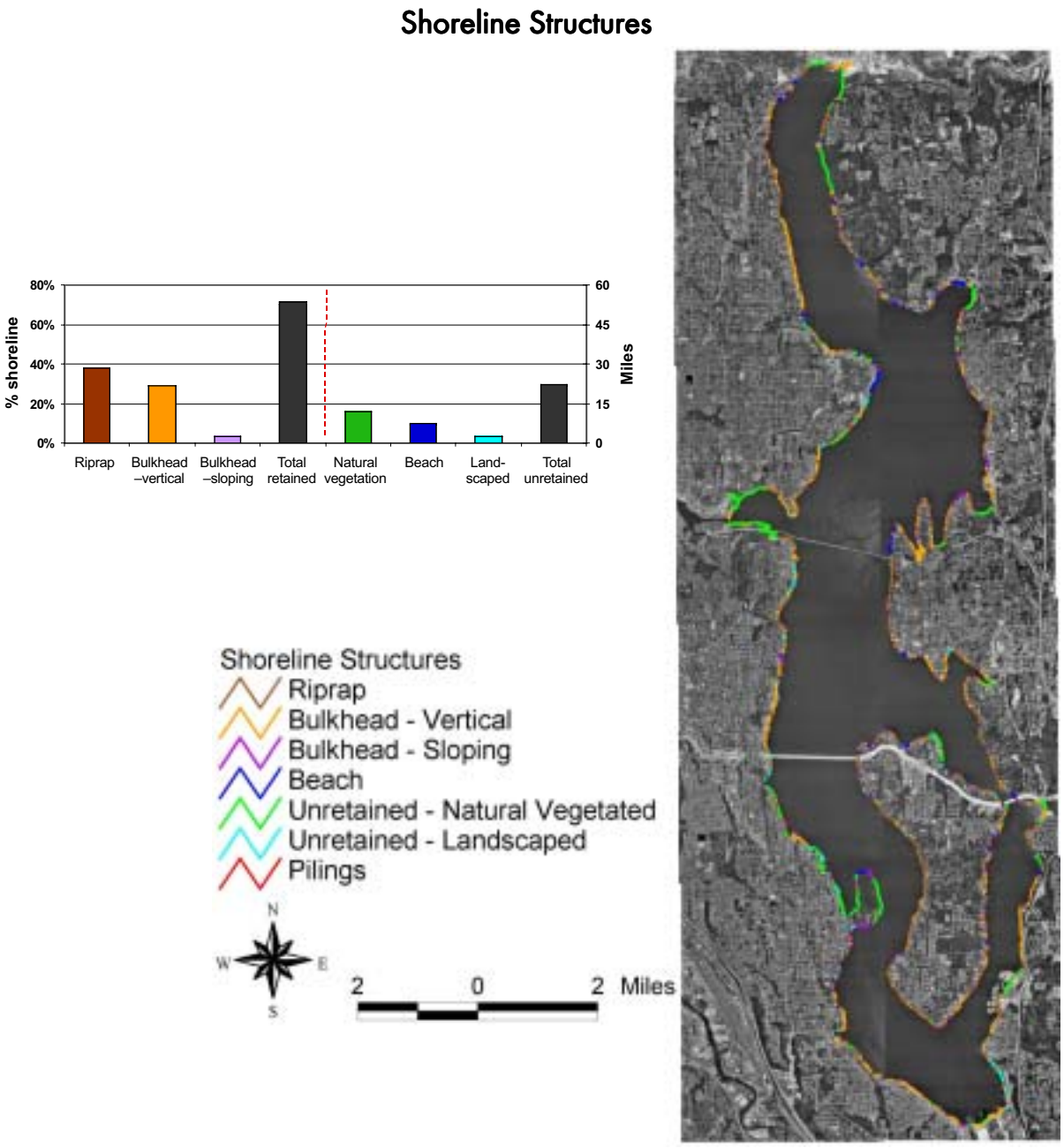

FIGURE. 6. Generalized categorizations of shoreline structure in Lake Washington. Lake level measurements during data collection ranged from 21.20 to 21.29 ft at the Kenmore gage.

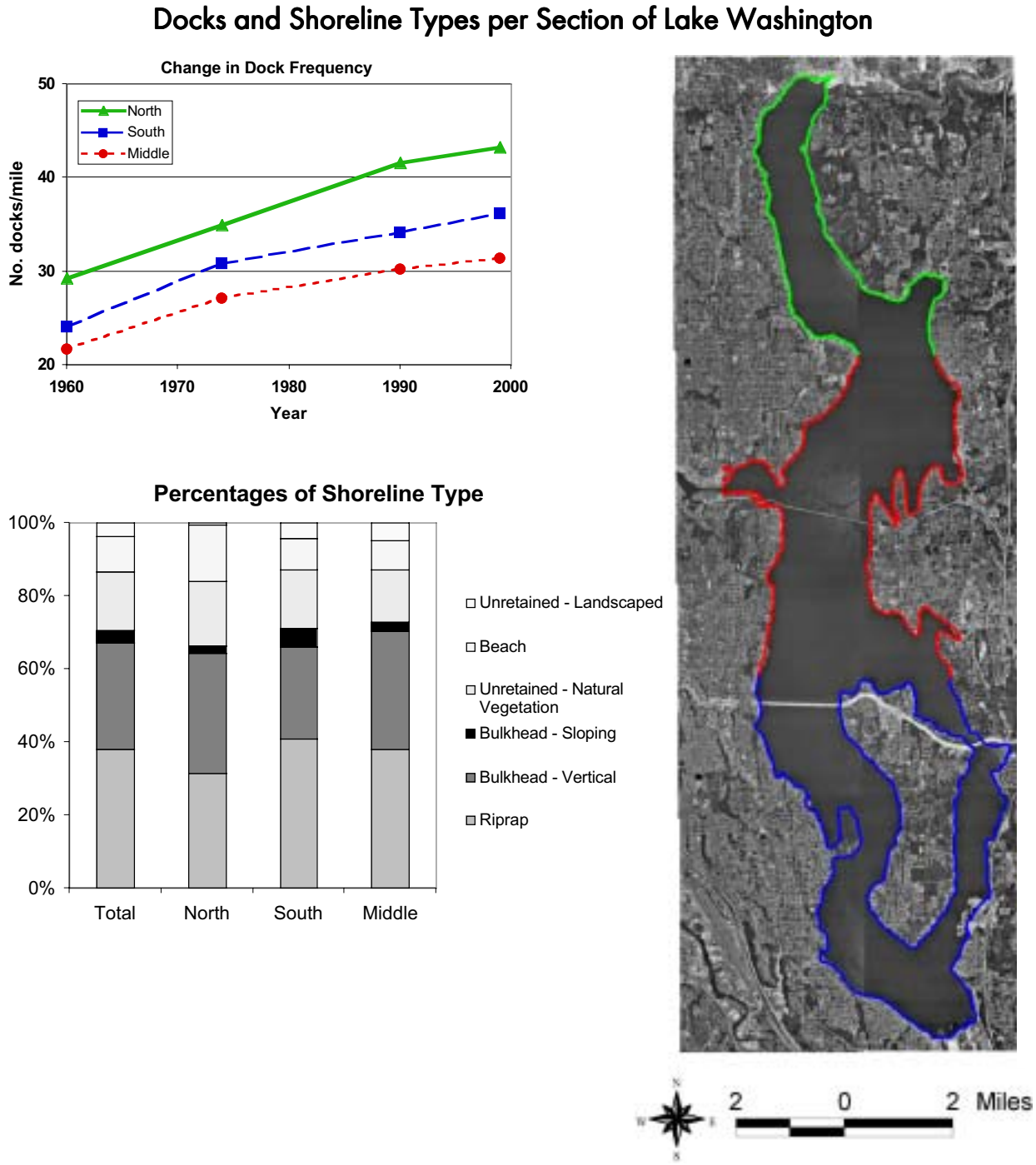

FIGURE 7. Historical change in dock frequency, and current classifications of shoreline type per geographic section of Lake Washington. Solid colors of shoreline type are retained, hatched are unretained.

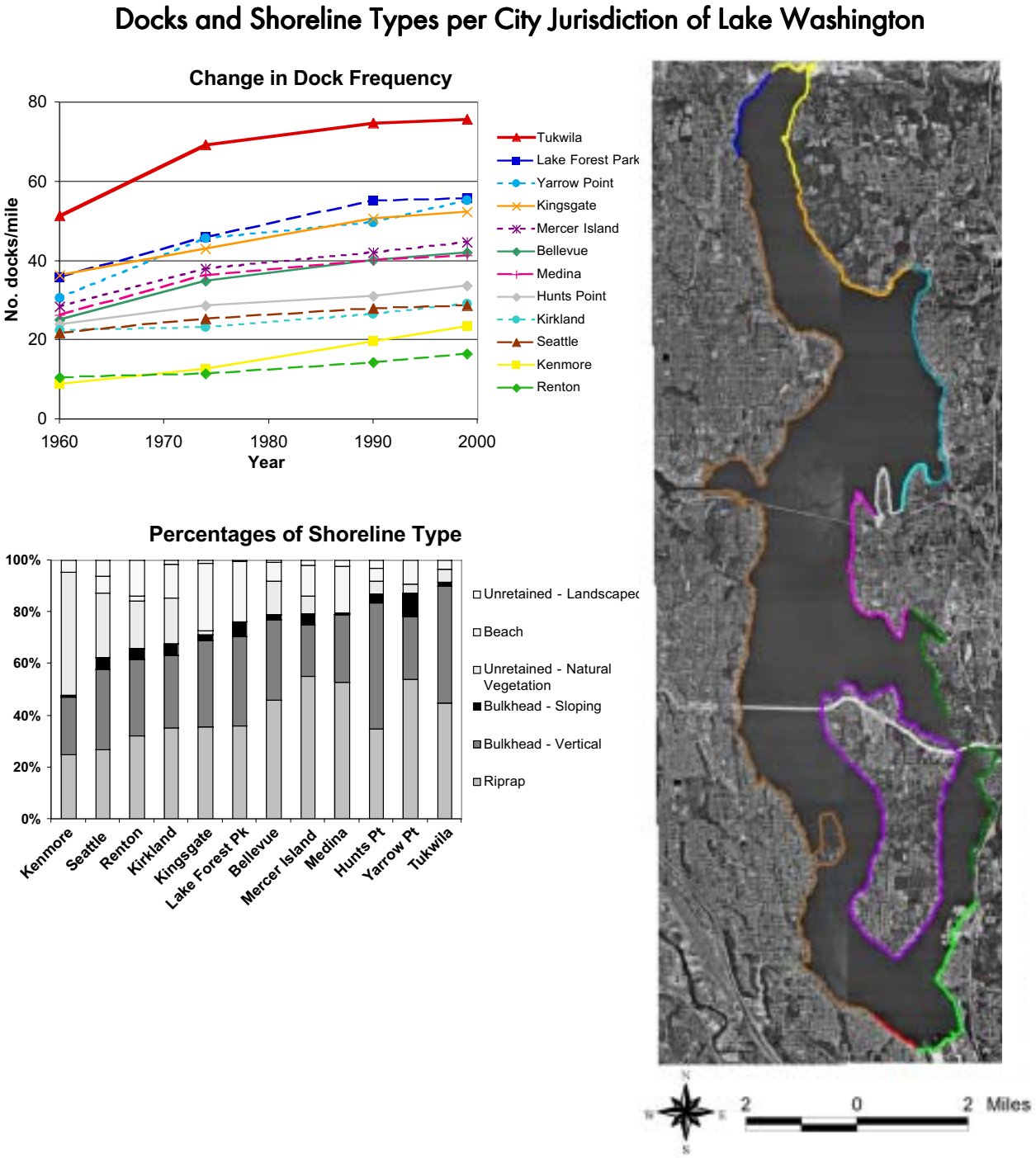

FIGURE. 8. Historical change in dock frequency, and current classifications of shoreline type per city jurisdiction of Lake Washington. Solid colors of shoreline type are retained, hatched are unretained.

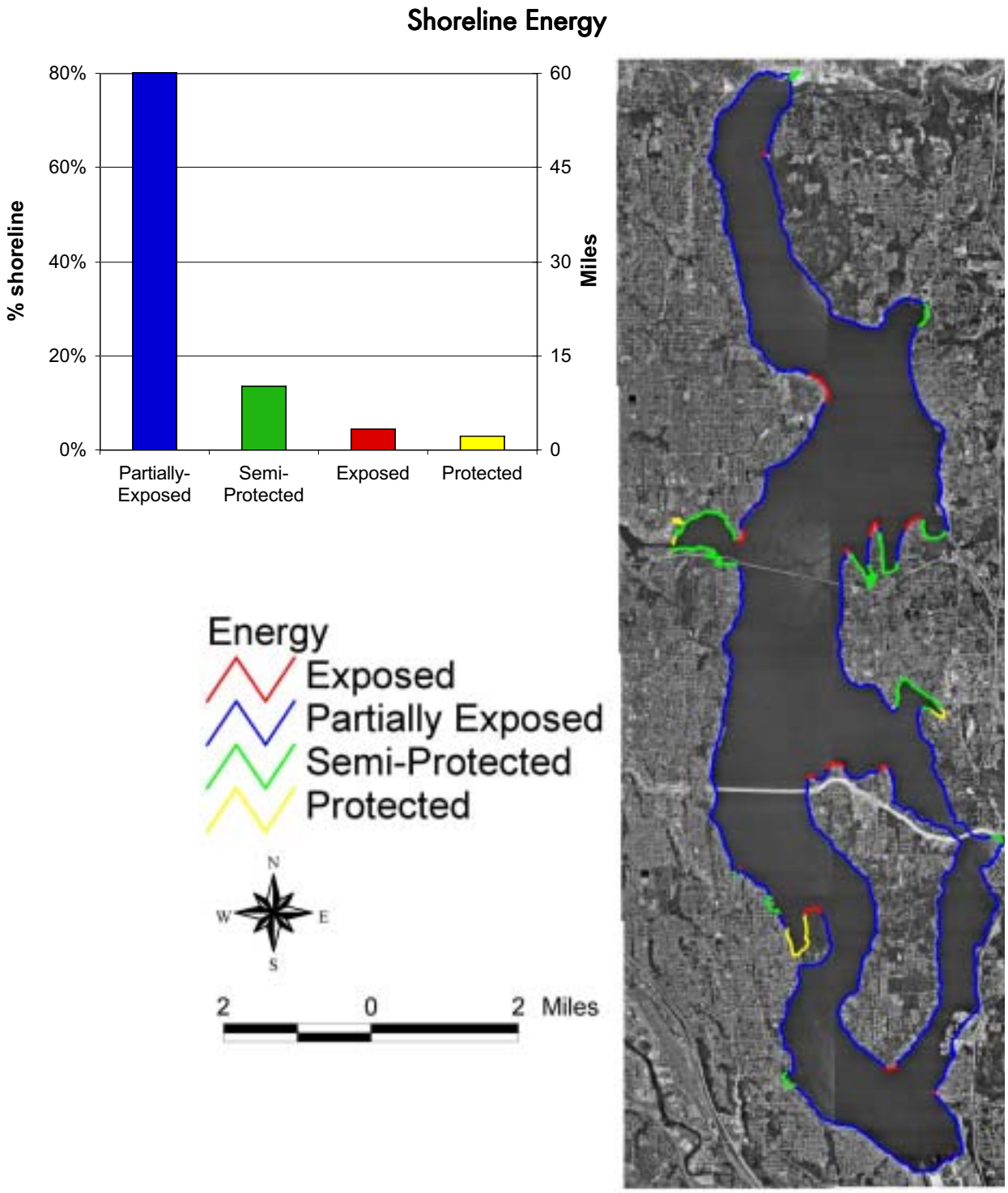

FIGURE 9. Generalized categorizations of shoreline energy in Lake Washington.

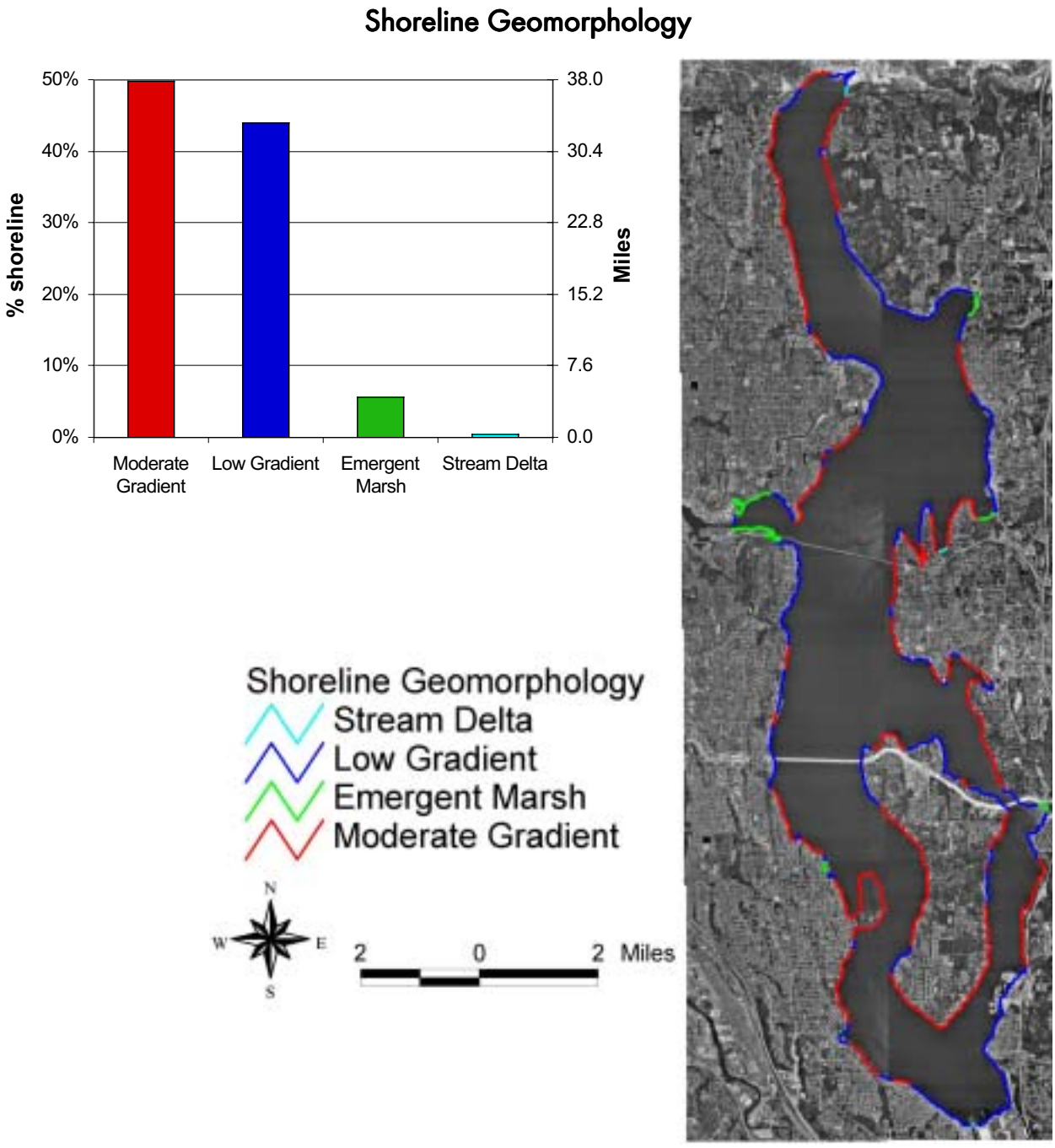

FIGURE 10. Generalized categorizations of shoreline geomorphology in Lake Washington.

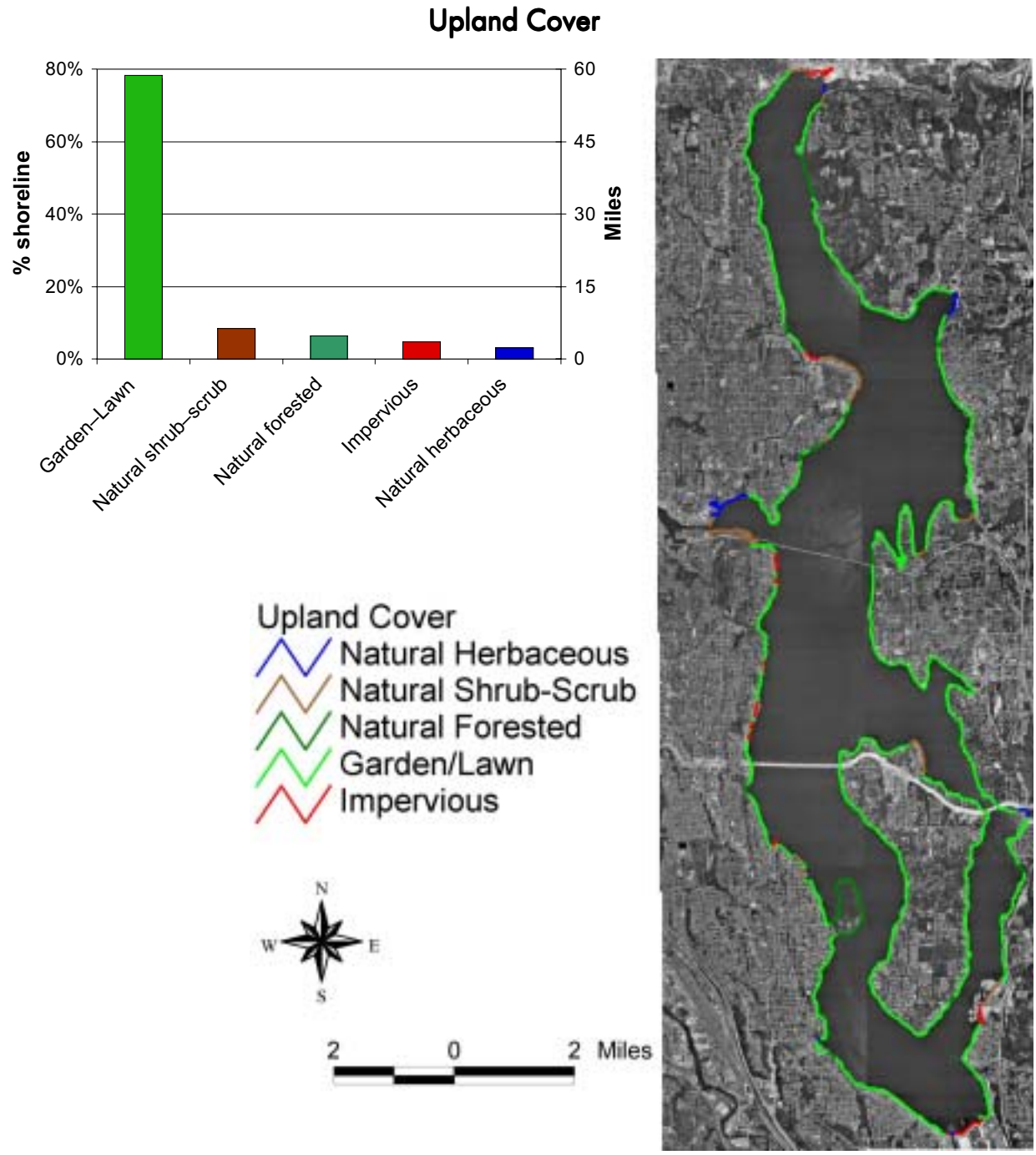

FIGURE 11. Generalized categorizations of upland cover in Lake Washington.

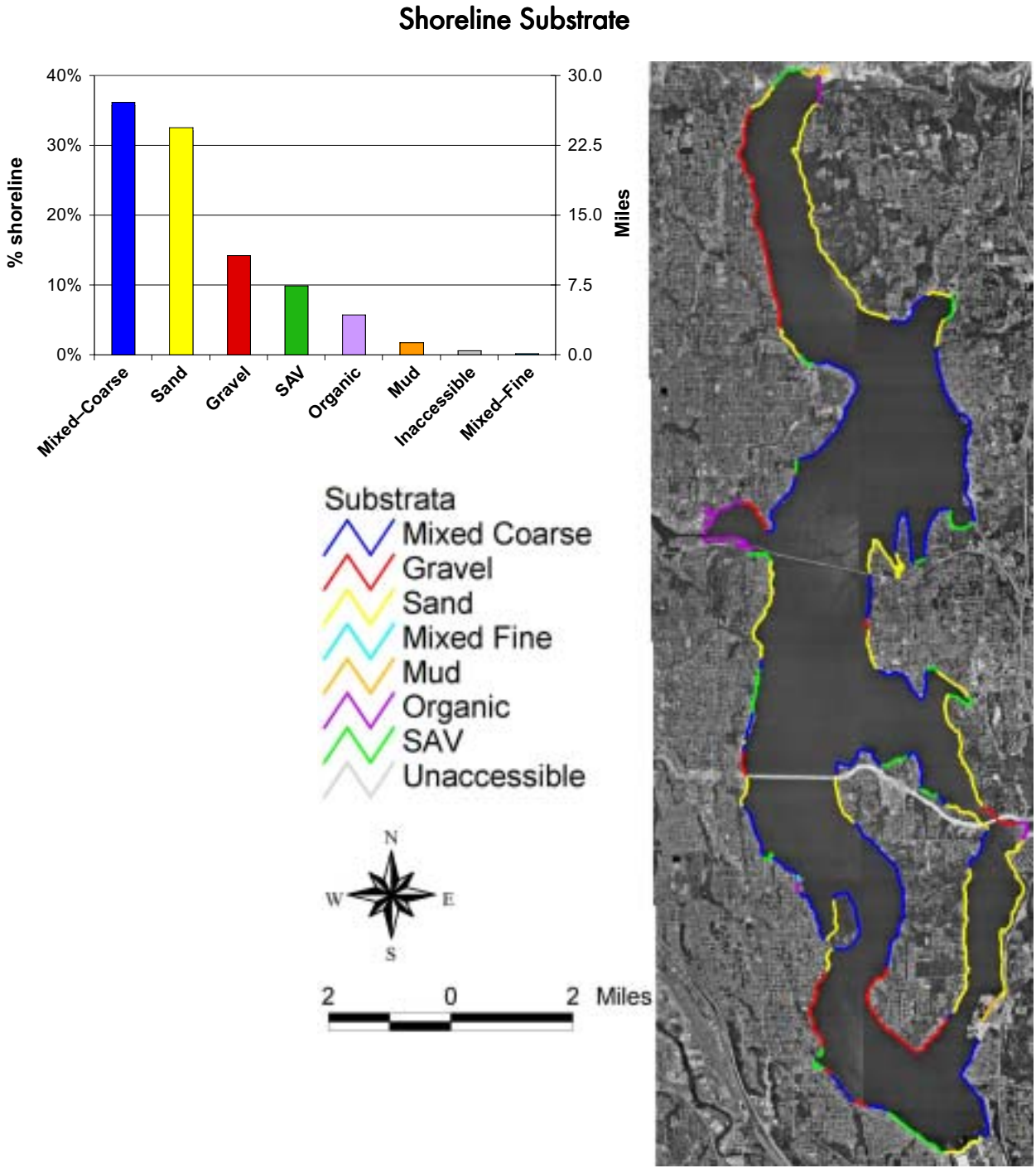

FIGURE 12. Generalized categorizations of dominant shoreline substrate in Lake Washington. SAV refers to Submerged Aquatic Vegetation covering the substrate. Unaccessible areas were blocked by log jams.

TABLE 1. Aerial photographs utilized for dock counts and layering of current shoreline modifications. The 1990 digital orthophotos were obtained from the University of Washington Map Collection, all other aerial photographs were obtained from Walker and Associates and scanned by Doug Houck at King County Metro.

Year	1960	1974	1990	1999
Type	Scanned aerial photograph	Scanned aerial photograph	Digital Orthophoto	Scanned aerial photograph
Scale	1:12000	1:18000	1:24000	1:24000
Date	4/7/1960; 6/23/1960	3/20/74	7/10/90	8/23/99

TABLE 2. Lake Washington shoreline classification scheme.

Modified from two well-accepted hierarchial wetland classification systems, the basic lacustrine classification of Cowardin et al. (1979) and Dethier's (1990) conceptual modifications. Following are the categories that were utilized in Lake Washington..

System: ***Lacustrine***
Subsystem: ***Limnetic; Littoral***
Class: ***Substrata*** (Natural)

Unconsolidated—Classifications pertain to major substrate type at the shoreline.
- Cobble: rocks < 256 mm (10") but > 64 mm (2.5") diameter - unstable.
- Mixed-coarse: substrata consisting of cobbles, gravel, shell, and sand.
- Gravel: small rocks or pebbles, 4-64 mm diam.
- Sand: 0.06-4 mm.
- Mixed-fine (sand-mud): mixture of sand and mud, with little gravel, likely to change seasonally.
- Mud: fine substrata < 0.06 mm, usually mixed with organics.
- Organic: substrata composed primarily of organic matter such as wood chips, leaf litter, other detritus.
- Submerged Aquatic Vegetation (SAV): substrata undetermined, as covered by dense SAV.

Subclass: *Energy*—wave exposure, somewhat subjective (Dethier, 1990)
- Exposed: highly exposed to waves and wind fetch.
- Partially-exposed: shoreline substantially exposed to waves.
- Semi-protected: shoreline moderately protected from waves.
- Protected: shoreline mostly restricted from waves.

Modifiers: *Shoreline Geomorphology*
- Stream delta
- Low-gradient: Terrestrial shoreline with a low gradual slope.
- Moderate gradient: Terrestrial shoreline with a moderately inclined slope.
- Emergent marsh

Shoreline Structures
- Bulkhead – Vertical
- Bulkhead – Sloping
- Riprap
- Natural Vegetation
- Beach
- Landscaped
- Pilings

Upland Cover
- Natural herbaceous
- Natural shrub-scrub
- Natural forested
- Garden/lawn
- Impervious

TABLE 3. Comparison between UW data and Hockett's (1976) data for 1974 dock counts.

	1974—Hockett data	1974—UW data	Difference (#)	Difference (%)
Total docks	2441	2311	130	5.3%
Recreational docks	2383	2238	145	6.1%
Large marina docks	58	73	15	25.9%

TABLE 4. Comparison between UW survey and the City of Seattle Built Shoreline Survey (Parametrix and NRC 1999).

	North Seattle		South Seattle	
	UW Survey	City of Seattle Survey	UW Survey	City of Seattle Survey
Total retained shoreline	67.60%	76%	58.97%	94%
Total unretained shoreline	32.40%	24%	41.03%	6%

Appendix A: Metadata of GIS Layers

Projection: Universal Transverse Mercator System – 1983 Zone 10
Spheroid: GRS 80
Central Meridian: -123
Reference Latitude: 0
Scale Factor: 0.9996
False Easting: 500000
False Northing: 0

USGS digital orthophoto quadrangles obtained from University of Washington Map Collection. All other data prepared by:

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Appendix B: Raw Data

Appendix B1. Raw data of shoreline types of geographic sections of Lake Washington.

Miles				
Shoreline Type	Total	North	South	Middle
Riprap	28.83	4.95	14.36	9.52
Bulkhead - Vertical	22.08	5.12	8.84	8.11
Bulkhead - Sloping	2.77	0.33	1.79	0.65
TOTAL RETAINED	53.68	10.40	24.99	18.28
Unretained - Natural Vegetation	12.04	2.80	5.66	3.58
Beach	7.42	2.40	3.03	1.99
Unretained - Landscaped	2.81	0.10	1.46	1.25
Pilings	0.03			
TOTAL UNRETAINED	22.30	5.29	10.15	6.82

Percent				
Shoreline Type	Total	North	South	Middle
Riprap	37.94%	31.51%	40.86%	37.91%
Bulkhead - Vertical	29.06%	32.64%	25.16%	32.31%
Bulkhead - Sloping	3.65%	2.13%	5.09%	2.60%
TOTAL RETAINED	70.65%	66.27%	71.11%	72.82%
Unretained - Natural Vegetation	15.85%	17.83%	16.11%	14.27%
Beach	9.76%	15.27%	8.63%	7.92%
Unretained - Landscaped	3.70%	0.63%	4.14%	5.00%
Pilings	0.03%			
TOTAL UNRETAINED	29.35%	33.73%	28.89%	27.18%

Appendix B2. Raw data of shoreline types of city jurisdictions of Lake Washington

Miles

Shoreline Type	Kenmore	Seattle	Renton	Kirkland	Kingsgate	Lake Forest Park	Bellevue	Mercer Island	Medina	Hunts Point	Yarrow Point	Tukwila
Riprap	0.88	7.07	1.35	1.81	1.30	0.70	3.04	7.65	2.35	0.93	0.79	0.48
Bulkhead - Vertical	0.79	8.13	1.22	1.42	1.23	0.66	2.05	2.80	1.17	1.29	0.35	0.48
Bulkhead - Sloping	0.02	1.15	0.18	0.25	0.08	0.11	0.13	0.58	0.02	0.09	0.14	0.02
TOTAL RETAINED	1.69	16.34	2.75	3.48	2.62	1.46	5.22	11.02	3.54	2.30	1.28	0.98
Unretained - Natural Vegetation	1.68	6.57	0.76	0.91	0.05		0.84	0.96	0.02	0.13	0.05	0.05
Beach	0.16	1.72	0.08	0.66	0.96	0.45	0.50	1.65	0.79	0.13	0.14	0.04
Unretained - Landscaped		1.61	0.58	0.08	0.04	0.01	0.04	0.27	0.10	0.08		
Pilings			0.03									
TOTAL UNRETAINED	1.84	9.90	1.44	1.65	1.05	0.46	1.39	2.88	0.91	0.35	0.19	0.09

Percent

Shoreline Type	Kenmore	Seattle	Renton	Kirkland	Kingsgate	Lake Forest Park	Bellevue	Mercer Island	Medina	Hunts Point	Yarrow Point	Tukwila
Riprap	24.89%	26.93%	32.11%	35.34%	35.57%	36.17%	45.94%	55.03%	52.86%	34.92%	54.02%	44.96%
Bulkhead - Vertical	22.28%	30.97%	29.17%	27.76%	33.46%	34.19%	31.06%	20.11%	26.24%	48.62%	23.97%	45.12%
Bulkhead - Sloping	0.66%	4.38%	4.33%	4.78%	2.31%	5.80%	2.03%	4.14%	0.37%	3.36%	9.35%	1.40%
TOTAL RETAINED	47.84%	62.27%	65.60%	67.88%	71.34%	76.16%	79.04%	79.29%	79.48%	86.90%	87.34%	91.49%
Unretained - Natural Vegetation	47.68%	25.04%	18.10%	17.66%	1.37%		12.74%	6.93%	0.37%	5.08%	3.35%	4.99%
Beach	4.48%	6.57%	1.97%	12.95%	26.23%	23.29%	7.55%	11.86%	17.85%	4.96%	9.31%	3.52%
Unretained - Landscaped		6.12%	13.73%	1.51%	1.06%	0.55%	0.67%	1.92%	2.31%	3.05%		
Pilings			0.60%									
TOTAL UNRETAINED	52.16%	37.73%	34.40%	32.12%	28.66%	23.84%	20.96%	20.71%	20.52%	13.10%	12.66%	8.51%

Appdneix B3. Raw data of dock numbers for geographic sections and city jurisdictions

dock/number

Year	Total	North	South	Middle	Tukwila	Lake Forest Park	Yarrow Point	Kingsgate	Mercer Island	Bellevue	Medina	Hunts Point	Kirkland	Seattle	Kenmore	Renton
1960	1849	459	845	545	55	69	45	133	396	166	117	63	115	573	31	44
1974	2322	548	1082	681	74	88	67	158	527	231	161	76	119	667	45	48
1990	2608	653	1198	757	80	106	73	186	583	265	179	82	136	733	69	60
1999	2737	679	1271	787	81	107	81	192	621	278	184	89	149	753	83	69
miles	75.98	15.7	35.145	25.11	1.07	1.92	1.47	3.67	13.90	6.61	4.45	2.65	5.13	26.24	3.53	4.19

docks/mile

Year	Total	North	South	Middle	Tukwila	Lake Forest Park	Yarrow Point	Kingsgate	Mercer Island	Bellevue	Medina	Hunts Point	Kirkland	Seattle	Kenmore	Renton
1960	24.3	29.24	24.04	21.70	51.40	35.94	30.61	36.24	28.49	25.11	26.29	23.77	22.42	21.84	8.78	10.50
1974	30.6	34.90	30.79	27.12	69.16	45.83	45.58	43.05	37.91	34.95	36.18	28.68	23.20	25.42	12.75	11.46
1990	34.3	41.59	34.09	30.15	74.77	55.21	49.66	50.68	41.94	40.09	40.22	30.94	26.51	27.93	19.55	14.32
1999	36.0	43.25	36.16	31.34	75.70	55.73	55.10	52.32	44.67	42.06	41.35	33.58	29.04	28.70	23.51	16.47

Appendix B4. Raw data of recreational and large marina dock numbers

Year	Recreational Docks	Large Marina Docks
1960	1792	57
1974	2238	73
1990	2499	109
1999	2626	111

Appendix B5. Raw data of high/low docks with attached structures

Dock Characteristics	Count for 1999	Percent
Low Dock w/o building	2464	91.02%
Low Dock w building	191	7.06%
High Dock w/o building	1	0.04%
High Dock w building	22	0.81%
Dock w Attached Floating Dock(s)	24	0.89%

Appendix B6. Raw data of general categories of shoreline classifications

Substrata

Name	Sum Length (miles)	Percentages
Mixed-Coarse	27.17	35.76%
Sand	24.41	32.13%
Gravel	10.69	14.07%
SAV	7.46	9.82%
Organic	4.30	5.66%
Mud	1.34	1.77%
Unaccessible	0.47	0.61%
Mixed-Fine	0.14	0.18%

Shoreline Energy

Name	Sum Length (miles)	Percentages
Partially-Exposed	60.09	79.13%
Semi-Protected	10.25	13.49%
Exposed	3.40	4.48%
Protected	2.20	2.90%

Shoreline Geomorphology

Name	Sum Length (miles)	Percentages
Moderate Gradient	37.85	49.82%
Low Gradient	33.46	44.04%
Emergent Marsh	4.27	5.62%
Stream Delta	0.40	0.52%

Upland cover

Name	Sum Length (miles)	Percentages
Garden/Lawn	58.76	77.33%
Natural Shrub-Scrub	6.39	8.41%
Natural Forested	4.87	6.42%
Impervious	3.61	4.76%
Natural Herbaceous	2.34	3.08%